

It is believed and respectfully submitted that the document titled "Series H; Audiovisual and Multimedia Systems" should not be included in an Information Disclosure Statement since it is not relevant. It is not understood why this reference was in the U.S.P.T.O file.

Claims 10 to 18 were rejected as lacking enablement under the first paragraph of 35 U.S.C. § 112.

The subject matter of claim 10 is described in the specification as follows: the "first measuring electrode is a cermet electrode, where at least one metal oxide component of the cermet electrode is capable of reversing incorporation of oxygen". Specification, page 4, lines 28 to 31. Claim 10 has been rewritten to better clarify its subject matter.

The subject matter of claim 13 is described in the specification as follows: the "cermet electrode may also contain as an added metal component a noble metal such as gold or silver." Specification, page 8, lines 12 to 13. Claim 13 has been rewritten to better clarify its subject matter.

It is therefore respectfully requested that the indefiniteness rejections be withdrawn.

As regards claims 14 and 15, it is respectfully submitted that as now presented, these claims are allowable. Additionally, the text at lines 5 to 15 of page 6 of the specification (as well as original claims 5 and 6 which are part of the original specification) plainly enable claims 14 and 15.

As further regards the enablement rejections under the first paragraph of 35 U.S.C. § 112, it is respectfully submitted that the standard for determining whether a patent application complies with the enablement requirement is that the specification describe how to make and use the invention -- which is defined by the claims. (See M.P.E.P. § 2164). The Supreme Court established the appropriate standard as being whether any experimentation for practicing the invention was undue or unreasonable. (See M.P.E.P. § 2164.01 (citing Mineral Separation v. Hyde, 242 U.S. 261, 270 (1916); In re Wands, 858 F.2d. 731, 737, 8 U.S.P.Q.2d 1400, 1404 (Fed Cir. 1988))). Thus, the enablement test is "whether one reasonably skilled in the art could make or use the invention from the disclosures in the patent coupled with information known in the art without undue experimentation." (See id. (citing United States v. Teletronics, Inc., 857 F.2d 778, 785, 8 U.S.P.Q.2d 1217, 1223 (Fed. Cir. 1988))).

As stated before, the Federal Circuit has made clear that there are many factors to be considered in determining whether a specification satisfies the enablement requirement, and

that these factors include but are not limited to the following: the breadth of the claims; the nature of the invention; the state of the prior art; the level of ordinary skill; the level of predictability in the art; the amount of direction provided by the inventor; the existence of working examples; and the quantity of experimentation needed to make or use the invention based on the disclosure. (See id. (citing In re Wands, 858 F.2d at 737, 8 U.S.P.Q.2d at 1404 and 1407)). In this regard, the Federal Circuit has also stated that it is “improper to conclude that a disclosure is not enabling based on an analysis of only one of the above factors,” and that the examiner’s analysis must therefore “consider all the evidence related to each of these factors” so that any nonenablement conclusion “must be based on the evidence as a whole.” (See M.P.E.P. § 2164.01). It is respectfully submitted that the Office Action has not addressed these factors.

Importantly, an examiner bears the initial burden of establishing why the “scope of protection provided by a claim is not adequately enabled by the disclosure.” (See id. (citing In re Wright, 999 F.2d 1557, 1562, 27 U.S.P.Q.2d 1510, 1513 (Fed. Cir. 1993))). Accordingly, a specification that teaches the manner and process of making and using an invention in terms that correspond in scope to those used in describing and defining the claimed subject matter complies with the enablement requirement. (See id.).

It is believed that the present assertions of the Office Action do not meaningfully address -- as they must under the law -- whether the present application enables a person having ordinary skill in the art to practice the claimed subject matter of the claims without undue experimentation -- which it plainly does. In short, it is believed that the Office Action’s arguments and assertions do not really address the issue of whether one having ordinary skill would have to *unduly experiment* to practice the claimed subject matter of the rejected claims -- a proposition for which the Office bears the burden of proving a prima facie case as to the rejected claims.

In this regard, to properly establish enablement or non-enablement, the Office must make use of proper evidence, sound scientific reasoning and the established law. In the case of Ex Parte Reese, 40 U.S.P.Q.2d 1221 (Bd. Pat. App. & Int. 1996), a patent examiner rejected (under the first paragraph of section 112) application claims because they were based on an assertedly non-enabling disclosure, and was promptly reversed because the rejection was based only on the examiner’s subjective belief that the specification was not enabling as to the claims. In particular, the subjective assertions of the Office Action are simply not supported by any real “evidence or sound scientific reasoning” -- which the law requires and

which makes plain that the Office (and not an applicant) bears the burden of persuasion on an enablement rejection.

More particularly, the examiner in Ex parte Reese was reversed because the rejection had only been based on a conclusory statement that the specification did not contain a sufficiently explicit disclosure to enable a person to practice the claimed invention without exercising undue experimentation -- which the Board found to be merely a conclusory statement that only reflected the subjective and unsupported beliefs of a particular examiner and that was not supported by any proper evidence, facts or scientific reasoning. (See id.). Moreover, the Board made clear that it is “incumbent upon the Patent Office . . . to back up assertions of its own with acceptable evidence,” and also made clear that “[where an] examiner’s ‘Response to Argument’ is not supported by evidence, facts or sound scientific reasoning, [then an] examiner has not established a *prima facie* case of lack of enablement under 35 U.S.C. § 112, first paragraph.” (See id. at 1222 & 1223; italics in original).

In the present case, it is respectfully submitted that the Office Action has not satisfied the foregoing for establishing that undue experimentation would be required, so that it is respectfully requested that the enablement rejections be withdrawn.

Claims 10 to 18 were rejected as indefinite under the second paragraph of 35 U.S.C. § 112. Although the definiteness rejections may not be agreed with, to facilitate matters, claims 10, 13, 14 and 17 have been rewritten to better clarify those claims. The subject matter of claim 10 is shown in Figure 1 of the present application such that the electrodes are on opposite sides of the solid electrolyte. Hence, claim 10 is not vague in reciting that the solid electrolyte is “situated between the first and second measuring electrodes”. It is therefore respectfully requested that the indefiniteness rejections be withdrawn.

Claims 10, 14, and 15 were rejected under 35 U.S.C. § 102(e) as anticipated by U.S. Patent No. 6,168,700 (“the Köhler reference”).

To anticipate a claim under § 102, a single prior art reference must identically describe each and every claim element. See Lindeman Maschinenfabrik v. American Hoist and Derrick, 730 F.2d 1452, 1458 (Fed. Cir. 1984). If any claimed element is absent from a prior art reference, it cannot anticipate the claim. See Rowe v. Dror, 112 F.3d 473, 478 (Fed. Cir. 1997). Anticipation requires the presence in a single prior art reference an identical description of each and every element of the claim invention, arranged as in the claim. Lindeman, 703 F.2d 1458.

In contrast to the reference relied upon, claim 10 includes a first electrode (first

measuring electrode), which is essentially not catalytically active *and which includes a metal-oxide component that is capable of the reversible incorporation of oxygen*. Such an electrode functions as an oxygen store. If  $\lambda$  drops in the waste gas to a value below 1 (low oxygen concentration), then the first electrode, because of the oxygen-storing effect of the metal-oxide component, stores oxygen, so that a potential of nearly  $\lambda = 1$  is applied at this electrode. The first electrode, thus, acts as reference electrode in the region  $\lambda < 1$  (cf. page 8 of the Substitute Specification (and page 6 of the German priority application)).

This important feature is not even referred to in the Office Action of February 14, 2003, since the reference relied upon does not include any reference to an electrode containing a metal oxide component capable of the reversible incorporation of oxygen. This feature provides the benefit providing for a potential of  $\lambda = 1$  being applied when a  $\lambda$  value of  $< 1$  is present in the gas mixture.

With respect to the references cited, they only refer to electrodes that do not catalyze a balance adjustment of the gas mixture, or which only catalyze it to a small degree.

Accordingly, the reference relied upon does not identically describe (or even suggest) all of the features of claim 10. It is therefore respectfully submitted that claim 10 is allowable, as are its dependent claims 14 and 15.

Claims 10 and 13 were rejected under 35 U.S.C. § 102(a) and 35 U.S.C. § 102(e) as anticipated by U.S. Patent No. 6,143,165 (Kurosawa '165) or U.S. Patent No. 5,897,759 (Kurosawa '759).

In contrast to the references relied upon, and as explained above, claim 10 includes a first electrode (first measuring electrode), which is essentially not catalytically active *and which includes a metal-oxide component that is capable of the reversible incorporation of oxygen*. Such an electrode functions as an oxygen store. If  $\lambda$  drops in the waste gas to a value below 1 (low oxygen concentration), then the first electrode, because of the oxygen-storing effect of the metal-oxide component, stores oxygen, so that a potential of nearly  $\lambda = 1$  is applied at this electrode. The first electrode, thus, acts as reference electrode in the region  $\lambda < 1$  (cf. page 8 of the Substitute Specification (and page 6 of the German priority application)).

This important feature is not even referred to in the Office Action of February 14, 2003, since the references relied upon do not include any reference to an electrode containing a metal oxide component capable of the reversible incorporation of oxygen. This feature provides the benefit providing for a potential of  $\lambda = 1$  being applied when a  $\lambda$

value of  $< 1$  is present in the gas mixture.

It is therefore respectfully submitted that claim 10 is allowable, as is its dependent claim 13.

Claim 14 was rejected under 35 U.S.C. § 103(a) as unpatentable over U.S. Patent No. 6,143,165 (Kurosawa '165) or U.S. Patent No. 5,897,759 (Kurosawa '759) in view of U.S. Patent No. 4,487,680 (Logothetis et al.).

For a claim to be rejected for obviousness under 35 U.S.C. § 103(a), the prior art must teach or suggest each element of the claim. See Northern Telecom, Inc. v. Datapoint Corp., 908 F.2d 931, 934 (Fed. Cir. 1990), cert. denied, 111 S. Ct. 296 (1990); In re Bond, 910 F.2d 831, 834 (Fed. Cir. 1990).

Claim 14 depends on claim 10, and is therefore allowable for essentially the same reason as claim 10, since the Logothetis reference does not cure the critical deficiencies of the Kurosawa references. Accordingly, claim 14 is allowable.

Claim 15 was rejected under 35 U.S.C. § 103(a) as unpatentable over U.S. Patent No. 6,143,165 (Kurosawa '165) or U.S. Patent No. 5,897,759 (Kurosawa '759), and U.S. Patent No. 4,487,680 (Logothetis et al.) in view of U.S. Patent No. 3,843,400 (Radford et al.) or U.S. Patent No. 6,218,036 (Shiratori).

Claim 15 depends on claim 10, and is therefore allowable for essentially the same reason as claim 10, since the further references relied upon do not cure the critical deficiencies of the Kurosawa references. Accordingly, claim 15 is allowable.

Claims 10, 12, and 13 were rejected under 35 U.S.C. § 102(e) as anticipated by U.S. Patent No. 6,019,881 (Kurosawa '881).

In contrast to the reference relied upon, and as explained above, claim 10 includes a first electrode (first measuring electrode), which is essentially not catalytically active *and which includes a metal-oxide component that is capable of the reversible incorporation of oxygen*. Such an electrode functions as an oxygen store. If  $\lambda$  drops in the waste gas to a value below 1 (low oxygen concentration), then the first electrode, because of the oxygen-storing effect of the metal-oxide component, stores oxygen, so that a potential of nearly  $\lambda = 1$  is applied at this electrode. The first electrode, thus, acts as reference electrode in the region  $\lambda < 1$  (cf. page 8 of the Substitute Specification (and page 6 of the German priority application)).

This important feature is not even referred to in the Office Action of February 14, 2003, since the reference relied upon does not include any reference to an electrode containing a metal oxide component capable of the reversible incorporation of oxygen. This

feature provides the benefit providing for a potential of  $\lambda = 1$  being applied when a  $\lambda$  value of  $< 1$  is present in the gas mixture.

Also, as explained above, with respect to the references cited, they only refer to electrodes that do not catalyze a balance adjustment of the gas mixture, or which only catalyze it to a small degree.

It is therefore respectfully submitted that claim 10 is allowable, as are its dependent claims 12 and 13.

Claims 10, 12, and 13 were rejected under 35 U.S.C. § 103(a) as unpatentable over U.S. Patent No. 6,019,881 (Kurosawa '881) in view of U.S. Patent No. 6,143,165 (Kurosawa '165) or U.S. Patent No. 5,897,759 (Kurosawa '759).

Claim 10 is allowable for essentially the same reasons explained above since the further Kurosawa references do not cure the critical deficiencies of the Kurosawa '881 reference. Accordingly, claim 10 is allowable.

Claims 12 and 13 depend on claim 10, and are therefore allowable for the same reasons as claim 10.

Claim 14 was rejected under 35 U.S.C. § 103(a) as unpatentable over U.S. Patent No. 6,019,881 (Kurosawa '881) with or without U.S. Patent No. 6,143,165 (Kurosawa '165) or U.S. Patent No. 5,897,759 (Kurosawa '759) in view of U.S. Patent No. 4,487,680 (Logothetis et al.).

Claim 14 depends on claim 10, and is therefore allowable for essentially the same reasons as claim 10, since none of the further references relied upon cure the critical deficiencies of the primary references, so that claim 14 is allowable.

Claim 15 was rejected under 35 U.S.C. § 103(a) as unpatentable over U.S. Patent No. 6,019,881 (Kurosawa '881) with or without U.S. Patent No. 6,143,165 (Kurosawa '165) or U.S. Patent No. 5,897,759 (Kurosawa '759) in view of U.S. Patent No. 4,487,680 (Logothetis et al.) and U.S. Patent No. 3,843,400 (Radford et al.) or U.S. Patent No. 6,218,036 (Shiratori).

Claim 15 depends on claim 10, and is therefore allowable for the same reasons as claim 10, since none of the further references relied upon cure the critical deficiencies of the primary references, so that claim 15 is allowable.

Claim 19 does not add any new matter, and is supported, for example, at page 8 of the specification. Claim 19 depends from claim 10, and is therefore allowable for the same reasons as claim 10.

In summary, it is respectfully submitted that all of claims 10 to 19 are allowable for the foregoing reasons.

### CONCLUSION

In view of all of the above, it is believed that the rejections have been obviated, and that claims 10 to 19 are allowable. It is therefore respectfully requested that the rejections be withdrawn, and that the present application issue as early as possible.

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**AMENDMENT VERSION WITH MARKINGS****IN THE CLAIMS:**

Without prejudice, please add new claim 19 as indicated above, and please amend the claims as follows:

10. (Amended) A sensor for determining a concentration of gas components in a gas mixture, comprising:

a first measuring electrode having substantially no catalytic effect on an establishment of an equilibrium in the gas mixture when exposed to the gas mixture, the first measuring electrode [being] including a cermet electrode [having] with at least one metal oxide component, the at least one metal oxide component being capable of reversible incorporation of oxygen;

a second measuring electrode catalyzing an establishment of an equilibrium in the gas mixture when exposed to the gas mixture; and

a solid electrolyte that is conductive for oxygen ions situated between the first and second measuring electrodes.

13. (Amended) The sensor according to claim 10, wherein the first measuring electrode is a mixed potential electrode [including] and includes a metal component that is at least one of gold and silver.

14. (Amended) The sensor according to claim 10, further comprising a porous layer, the solid electrolyte being integrated into the porous layer.

15. (Amended) The sensor according to claim 14, wherein the porous layer contains at least one of promoters and catalysts at least in some areas.

17. (Amended) The sensor according to claim 10, further comprising a porous layer extending between the first and second measuring electrodes, one of the first and second measuring electrodes being situated on a side of the sensor facing the gas mixture, another of the measuring electrodes being situated between a reference electrode and the one of the



**AMENDMENT VERSION WITH MARKINGS**

measuring electrodes facing the gas mixture, the solid electrolyte being integrated into the porous layer.



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SENSOR FOR DETERMINING A CONCENTRATION OF  
GAS COMPONENTS IN GAS MIXTURES

[The present invention relates to a sensor for determining a concentration of gas components in gas mixtures having the features characterized in Claim 1.]

Background Information

Sensors for determining the concentration of gas components in gas mixtures, in particular in gases from internal combustion engines, are known. Such sensors are used to preset a fuel/air mixture for operation of the internal combustion engine on the basis of a determination of the oxygen concentration and/or the concentration of reducing gas components such as HC or CO. A specific operating state can be characterized by using the ratio of the oxygen concentration to the fuel concentration. If there is a stoichiometric excess of fuel (rich range), the amount of oxygen in the exhaust gas will be small in comparison with other components, which are partially uncombusted. In the lean range, where oxygen from air is predominant in the fuel/air mixture, the oxygen concentration in the exhaust gas is accordingly high.

To determine the oxygen concentration in the exhaust gas, there are known lambda sensors which detect a lambda value  $> 1$  in a lean range, a lambda value  $< 1$  in the rich range and a lambda value  $= 1$  in a stoichiometric range. In a known manner, an electrochemical measuring cell of the sensor supplies a detection voltage which is sent to a circuit arrangement. The detection voltage depends on an oxygen concentration difference at the at least two measuring electrodes used. A solid electrolyte body which is conductive for oxygen ions is arranged between the measuring electrodes. The detection

MARKED-UP VERSION OF SPECIFICATION

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voltage increases or decreases according to the oxygen concentration in the exhaust gas.

In addition, there are known sensors which are used to determine the concentration of the reducing gas components. These sensors are often component specific, i.e., there is a separate sensor for each gas component ( $H_2$ , HC and CO) to be detected.

Both types of sensor supply either a value for the oxygen concentration or the concentration of the reducing gas components. Thus, they supply values which give only an indirect indication of the status of the lambda value. Thus, a sensor for determining oxygen concentrations can supply a certain absolute oxygen concentration from which it is possible to infer the composition of the fuel/air mixture.

A more precise setting of a control status of an internal combustion engine can be achieved by determining the lambda value directly. It is advantageous here to have a compact sensor capable of handling both sensor functions instead of two separate sensors, one for each gas component. Previous attempts to accommodate multiple sensor functions on one substrate have resulted in a complicated layout or a complicated layer structure which has a greater susceptibility to faults and entails high manufacturing costs.

The reducing gas components in the exhaust gas of internal combustion engines are in a thermodynamic equilibrium with the oxygen. The further away the sensors are arranged from the engine in an exhaust duct of the internal combustion engine, the lower the temperature of the exhaust gas, and thus it is difficult to establish a thermodynamic equilibrium from a kinetic standpoint. It is known that the equilibrium reaction can be catalyzed with transition metals. In particular,

catalysts containing platinum, palladium or rhodium have proven suitable. In using these metals as the electrode material for the measuring electrodes of sensors, it has proven especially advantageous to have such a catalytic activity on a measuring electrode which is exposed to the exhaust gas. In this way, the oxygen concentration at this measuring electrode can be kept very low, thus yielding a very high potential difference with respect to another electrode exposed to a reference gas. However, such a measuring electrode which catalyzes the establishment of an equilibrium in the gas mixture (equilibrium electrode) does not permit detection of the concentration of the reducing gas components.

Therefore, it is known that materials which inhibit a catalytic effect of the measuring electrode can be added to the measuring electrode exposed to the gas mixture. Thus, German Patent No. 44 08 361 [C2] describes a measuring electrode in which adsorption of oxygen on a surface of the measuring electrode has been made possible by the addition of bismuth, platinum, antimony or lead. Thus, the oxygen concentration, which determines the potential of the measuring electrode, at a ternary boundary of the measuring electrode is kept almost constant in operation of the internal combustion engine at  $\lambda > 1$ . The measuring electrode designed in this way reacts essentially to oxygen and is thus a non-equilibrium electrode or a mixed potential electrode. Such a measuring electrode can thus be used as a reference electrode at  $\lambda > 1$ .

In addition, it is known from German Patent No. 44 08 504 that such a mixed potential electrode can be designed by admixture of gold and/or silver. Due to the admixture of gold and/or silver, the catalytic conversion is inhibited by oxidation of CO and/or HC and reduction of  $\text{NO}_x$ . The high affinity of these metals for the reducing gas components is utilized at the

measuring electrode. The oxygen concentration and thus the potential of the mixed potential electrode can be kept almost constant due to adsorption of the reducing gas components at the surface of the mixed potential electrode in operation of the internal combustion engine at  $\lambda < 1$ . In this way, such a measuring electrode can be used as a reference electrode at  $\lambda < 1$ . One disadvantage of these two described embodiments of mixed potential electrodes is that they permit only constant potentials for two extreme positions of the  $\lambda$  value and thus omit the range at  $\lambda$  values  $\approx 1$ , which is especially interesting for control of the control status of the internal combustion engine. In addition, it is impossible in this way to determine the oxygen concentration on the one hand or the concentration of reducing gas components on the other hand by using one and the same measuring electrode.

#### [Advantages of the] Summary Of The Invention

It is possible to determine either the oxygen concentration or the concentration of a reducing gas component with an arrangement of just two measuring electrodes by [means of the features of Claim 1 and by] using the sensor according to the present invention for determining a concentration of gas components in gas mixtures having a first measuring electrode (mixed potential electrode) which has little or no catalytic effect on the establishment of an equilibrium in the gas mixture and a second measuring electrode (equilibrium electrode) which catalyzes the establishment of an equilibrium in the gas mixture as well as a solid electrolyte that is conductive for oxygen ions arranged between the two measuring electrodes, with the two measuring electrodes being exposed to the gas mixture. Due to the fact that at least the first measuring electrode is a cermet electrode, where at least one metal oxide component of the cermet electrode is capable of reversible incorporation of oxygen, the potential of this

first measuring electrode is kept almost constant in the range around  $\lambda \approx 1$ . Thus, the first measuring electrode is the reference electrode in this operating state of the internal combustion engine, while the second measuring electrode functions as the working electrode. If the operating state of the internal combustion engine changes to a range with  $\lambda > 1$ , then the potential of the second measuring electrode is almost constant, while the potential of the first measuring electrode is variable and is determined essentially by the concentration of the reducing gas components. Thus in this case the second measuring electrode is the reference electrode and the first measuring electrode is the working electrode.

Suitable metal oxide components for the first measuring electrode include, for example, the mixed oxides such as  $\text{TiNiNbO}_x$  or  $\text{FeNiMnO}_4$ . Furthermore, a noble metal such as gold may also be incorporated into the first measuring electrode. It is thus possible to adapt the potential of the first measuring electrode very accurately to the requirements of a given application.

In a preferred embodiment of the present invention, a reference electrode additionally exposed to a reference gas is provided for the two measuring electrodes exposed to the gas mixture. The measuring electrodes may be arranged side by side, i.e., both in the same layer of a multilayer sensor. However, it is also conceivable for the two measuring electrodes to be arranged one after the other in different layers, starting from an outer side of the sensor in the direction of the reference electrode. One layer between the two measuring electrodes must be sufficiently porous so that it allows a sufficiently rapid establishment of an equilibrium in the constantly changing concentrations of the individual exhaust gas components. One measuring electrode corresponds to the mixed potential electrode based on oxygen-storing metal

oxide components and the other measuring electrode is designed as an equilibrium electrode.

5 It has proven advantageous to arrange the mixed potential electrode closer to the exhaust gas because it has an especially stable and constant potential in rapid gas changes at lambda values around 1. In addition to an equilibrium electrode which naturally has a catalytic activity, it is also conceivable to incorporate additional catalysts or promoters  
10 into the porous intermediate layer, although of course not in the immediate vicinity of the mixed potential electrode. In this way, it is possible to have a controlled influence on the establishment of an equilibrium in the mixture, thus yielding the possibility of using other metal components that are not  
15 catalytically active for the equilibrium electrode.

With the help of this preferred arrangement with a total of only three electrodes, the oxygen concentration and the concentration of the reducing gas components can be determined  
20 simultaneously in certain operating states and thus the status of the lambda value can be determined directly. This permits a much more rapid and accurate establishment of the control status of the internal combustion engine. In addition, such a sensor can be implemented in an especially simple and  
25 inexpensive manner.

[Other preferred embodiments of the present invention are derived from the other features characterized in the subordinate claims.

30 Drawing

The present invention is illustrated in greater detail below in embodiments on the basis of the respective drawings.]

### Brief Description Of The Drawings

Figure 1 shows a schematic sectional view through a sensor[, and].

- 5 Figure 2 shows a schematic sectional view through another embodiment of a sensor.

### Detailed Description [of Embodiments]

10 Figure 1 shows a sensor 10 which can be used for determination of the concentration of gas components in gas mixtures, in particular the exhaust gases of internal combustion engines. Such a sensor 10 is preferably composed of individual ceramic layers which may be structured in a known way by screen printing, lamination, cutting, sintering or the like. Sensor  
15 10 contains an electrochemical measuring cell 12 having a first measuring electrode 14 and a second measuring electrode 16, with a porous oxygen ion conducting layer 18 extending between two measuring electrodes 14, 16. A heating element 22 is arranged beneath second measuring electrode 16 in a layer  
20 20 which at least conducts heat well. Heating element 22 includes a resistance element 24, designed as a meandering element here, and it functions to establish or control an operating temperature of sensor 10. Second measuring electrode 16 is composed of a noble metal cermet, e.g., based on a noble  
25 metal such as platinum. This second measuring electrode 16 is referred to below as equilibrium electrode 16 because of the catalytic activity of these noble metals with regard to the equilibrium reaction between oxygen and reducing gas components of the exhaust gas as explained below. As also to  
30 be explained below, first measuring electrode 14 has little or no catalytic activity in certain operating states of the internal combustion engine, which can be characterized by a lambda value, and it is referred to below as mixed potential electrode 14.

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During combustion of a fuel/air mixture in the internal combustion engine, reducing gas components which can react with the oxygen and are thus in a thermodynamic equilibrium with it are formed in variable amounts. In addition to a temperature-dependent equilibrium status of this reaction, the kinetics of the reaction is especially important for establishing the equilibrium. It may essentially be assumed that the temperature of the exhaust gas drops with an increase in the distance of sensor 10 from the engine, and thus it becomes more difficult for a thermodynamic equilibrium to be established from a kinetic standpoint. Due to the noble metals such as platinum, palladium and rhodium used in equilibrium electrode 16, establishment of this equilibrium is catalyzed. Thus, the potential of equilibrium electrode 16 is determined essentially by the oxygen concentration.

The potential of mixed potential electrode 14, however, does not depend on the oxygen concentration, at least in some ranges, but instead it is a function of the concentration of reducing gas components. It is thus possible to influence the potential of mixed potential electrode 14 in a controlled manner by selecting at least one metal oxide component capable of reversible incorporation of oxygen. Such a mixed potential electrode 14 may be made mostly of  $\text{TiNiNbO}_x$  or  $\text{FeNiMnO}_4$ . It is also conceivable to use metal oxides such as  $\text{Mn}_2\text{O}_3$  and  $\text{CeO}_2$ . In addition, the cermet electrode may also contain as an added metal component a noble metal such as gold or silver. In this way, the potential of mixed potential electrode 14 can be adapted individually to the requirements of given applications.

In an operating mode of internal combustion engine where  $\lambda \approx 1$ , the oxygen concentration directly at a surface of mixed potential electrode 14 is kept almost constant due to the added metal oxide components. A capacity for incorporation and

disincorporation of oxygen in a mixed potential electrode 14 determines a lambda range in which the potential of mixed potential electrode 14 is almost constant. However, the potential on equilibrium electrode 16 in such an operating mode of the internal combustion engine is exposed to great variations, because there are great variations in oxygen concentration precisely in such a lambda range. Thus at  $\lambda \approx 1$ , mixed potential electrode 14 can be used as a reference electrode, while equilibrium electrode 16 can be used as a working electrode 16. Then a detection voltage U which is a direct measure of the oxygen concentration of the gas mixture can be picked off via electrochemical measuring cell 12.

When the operating mode of the internal combustion engine changes to a range of  $\lambda > 1$ , then the potential of mixed potential electrode 14 changes greatly with a change in the concentration of the reducing gas components. However, the potential of equilibrium electrode 16 is almost constant at high oxygen concentrations. Thus in this case, equilibrium electrode 16 functions as the reference electrode and mixed potential electrode 14 functions as the working electrode. Then a detection voltage U corresponding to the concentration of the reducing gas components can be picked off via electrochemical measuring cell 12.

In principle, an arrangement of two measuring electrodes 14, 16 may be in the opposite order from that shown here, but in the case of the arrangement shown here, additional promoters or catalysts that support the establishment of an equilibrium may be incorporated into layer 18. In this way it is possible to vary the composition of equilibrium electrode 16 to a great extent, and it is not necessary to use such relatively expensive noble metals as platinum or palladium.

Figure 2 shows a preferred additional embodiment of sensor 10.

In addition to two measuring electrodes 14, 16 described above, sensor 10 has another reference electrode 26. Reference electrode 26 is above a reference channel 28 which is filled with a reference gas. Heating device 22 is used first for heating sensor 10 and also for heating the reference gas. Between reference electrode 26 and equilibrium electrode 16 there is a layer 30 composed of a solid electrolyte that is conductive for oxygen ions.

Such a sensor 10 has a first electrochemical measuring cell 32, which includes mixed potential electrode 14 and reference electrode 26, and a second electrochemical measuring cell 34, which includes equilibrium electrode 16 and reference electrode 26.

With the help of this very simple arrangement with only three electrodes, the oxygen concentration and the concentration of the reducing gas components can be measured simultaneously as a function of the operating mode of the internal combustion engine. In this way, a lambda value can be determined very rapidly and with high precision.

Thus, for example, at a lambda value  $> 1$ , the potential of mixed potential electrode 14 depends essentially on the concentration of the reducing gas components, as mentioned above, and thus it can be picked off as a detection voltage  $U_1$  via electrochemical measuring cell 32. In the same operating mode, a potential difference between equilibrium electrode 16 and reference electrode 26 can also be detected if the reference gas has a sufficiently different oxygen concentration. The potential difference then leads to a detection voltage  $U_2$  which can be picked off at electrochemical measuring cell 34 and is a direct measure of the oxygen concentration.

In addition to the arrangement shown here, where measuring electrodes 14, 16 are arranged in successive layers of sensor 10, an arrangement in one and the same layer is also conceivable. In this way, sensor 10 is also simpler to manufacture, i.e., fewer steps are involved.

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Abstract Of The Disclosure

A sensor [is described] for determining a concentration of gas components in gas mixtures having a first measuring electrode (mixed potential electrode) which has little or no catalytic effect on the establishment of an equilibrium in the gas mixture and a second measuring electrode (equilibrium electrode) which catalyzes the establishment of an equilibrium in the gas mixture as well as a solid electrolyte that is conductive for oxygen ions arranged between the two measuring electrodes, with the two measuring electrodes being exposed to the gas mixture. [

]At least the first measuring electrode (16) is a cermet electrode, where at least one metal oxide component of the cermet electrode is capable of reversible incorporation of oxygen.

[

(Figure 1)

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